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EFFECT OF SUCROSE, L-ASCORBIC ACID AND PECTIN ON THE QUALITY OF FROZEN STRAWBERRIES

Waldemar Kmiecik, Grażyna Jaworska, Zofia Lisiewska
Department of Raw Materials and Processing of Fruit and Vegetables, Agricultural University of Cracow, Poland

ABSTRACT

The aim of the work was to determine the effect of sugar, pectin, and L-ascorbic acid added to strawberries on the selected physico-chemical and organoleptic traits of the frozen product. Powdered sugar at a dose of 10 g per 100 g of fruit or as the 60% syrup was used without any other substance or with an addition of pectin or ascorbic acid. The pectin preparation in a 1,5% solution at a dose of 10 g per 100 g of fruit was used with or without the ascorbic acid.

The applied substances had a significant effect on the chemical composition of frozen strawberries. In relation to the raw material storage for the period of 12 months induced a small increase (by 1,5-3,2%) in the level of dry matter and the preservation or a slight decrease in the content of sugars (by 0,7-3,0%) and total acids (by 0,0-4,1%). The level of pH insignificantly increased. Moreover, the content of total phenols and anthocyanins was moderately reduced (by 7-26% and 10-33%, respectively), while a significant decrease of 30-60% was found in the level of vitamin C. Of the applied substances sugar syrup and a solution of the pectin preparation had the strongest protective effect on vitamin C in the fruit. Powdered sugar had such an effect on the content of anthocyanins.

In general, the substances used in the work positively affected the sensory traits of frozen fruit. Sugar, especially in the powdered form, favourably affected the preservation of shape, colour, consistency, and aroma of strawberries. The addition of the pectin to powdered sugar and to sugar syrup partly improved the consistency and taste, reducing the aroma of the frozen fruit. The addition of L-ascorbic acid to powdered sugar, sugar syrup, or the pectin solution did not

induce any significant change in the estimated quality factors.

In practice, sugar in the powdered form or as a syrup can be recommended for strawberry freezing. The pectin preparation as a 1,5% solution can be used in the production of frozen strawberries for diabetics and persons limiting the consumption of sugar in their diet.

Key words: frozen strawberries, additions, physico-chemical indices, organoleptic traits

INTRODUCTION

The strawberry occupies an important position in the Polish industry of fruit freezing. This is evidenced by the value of the annual export of frozen strawberries exceeding 100 thousand tons [Jędrzejewska and Wachowicz]. The large scale of frozen strawberry production can be attributed to the short storage life of fresh fruit and to the very wide scale of its use as a frozen product. It is also highly significant that of the different fruit species frozen strawberry probably preserves the traits of its taste and aroma to the greatest degree.

During freezing, storage of frozen fruit, and its thawing the deterioration of fruit quality in relation to the raw material is due to various reactions of oxidative character. The deterioration appears with variable intensity in different species and cultivars and intensifies with the elongation of the storage period. It concerns both the nutritive and organoleptic quality of the products [Kmiecik et al. 1995, 1996].

Antioxidants might considerably improve the organoleptic quality of frozen fruit but synthetic compounds of such effects evoked certain criticism as dangerous for human health. It is much more justified to use natural compounds, which in some conditions and at a proper concentration can protect vitamin C, pigments, and also organoleptic properties of the product [{Hong-Deng and Ueda 1993]. In the case of frozen fruit the most frequently used are such substances as sucrose in the loose form or as a solution, and also glucose, ascorbic acid, and pectin preparations. The above substances can be used separately or in combinations, this usually intensifying their effect.

The aim of the work was to evaluate the effect of sucrose, L-ascorbic acid, and pectin, applied in various forms and combinations, on the quality of frozen strawberries served as desserts.

MATERIAL AND METHODS

The strawberry cv. Dukat was used for freezing. Analyses of the raw material and processing were carried out within 4-6 hours of harvest. The preparation for freezing included the sorting and calibration of fruits with respect to size (20-25 mm in diameter) and colour, washing and draining on sieves, drying and detaching the petiole. The fruit was packed in flat polyethylene containers 500 g in volume.

The materials added to the strawberries were powdered sugar, 60% sugar syrup prepared from white refined sugar, low-methylated pectin, and L-ascorbic acid.

The following tests were used in order to show the effect of the selected substances used as natural antioxidants on the quality of frozen strawberries intended for serving as desserts:

1. Frozen strawberry without additional substances.

2. Frozen strawberry in sugar (500 g of fruit with 50 a of powdered sugar).
3. Frozen strawberry in sugar with pectin (500 g of fruit powdered with 50 g of sugar with the addition of 0,5 g of a pectin preparation).
4. Frozen strawberry in sugar with L-ascorbic acid (500 g of fruit powdered with 50 g of sugar with 0,25 a of L-ascorbic acid).
5. Frozen strawberry in sugar syrup (500 g of fruit dipped in 60°% sugar syrup. The amount of the syrup was supplemented to 84 g in the container, this corresponding to about 50 a of powdered sugar).
6. Frozen strawberry in sugar syrup with pectin (500 g of fruit dipped in the syrup containing 60% of sugar and 0,5% of the pectin preparation, on account of the high viscosity the temperature of the solution was 50°C. The amount of sugar was then supplemented to that corresponding to 50 g of sugar).
7. Frozen strawberry in sugar syrup with L-ascorbic acid (500 g of fruit dipped in syrup containing 50% of sugar and 0,5% of L-ascorbic acid. The amount was then supplemented to 84 g, this corresponding to about 50 g of sugar and 0,42 g of L-ascorbic acid).
8. Frozen strawberry in a pectin solution (500 g of fruit dipped in a 1,5% solution of the pectin preparation. The fruit retained 50 g of the solution).
9. Frozen fruit in the solution of pectin and L-ascorbic acid (500 g of fruit dipped in the solution containing 1,5% of the pectin preparation and 0,5% of L-ascorbic acid. Fruits retained 50 g of the solution containing 0,25 g of L-ascorbic acid).

All the samples were frozen in a Feutron blast freezer (3626-51) with a forced air current. The freezing at -40°C took about 90 min. During this time the temperature of -30°C was reached in the thermal centre of the fruits. Further storage of frozen products for the period of one year at -28°C to -30°C was carried out in a cold room.

Physico-chemical analyses of the raw material and of frozen products were conducted in four replications after 18-hour thawing at 2-4°C. The discriminants of the chemical composition were determined, using methods given in the sources quoted below: dry matter, total sugars, total acids, active acidity [AOAC 1984], vitamin C [ISO 16557/2 1984], anthocyanins [Fuleki and Francis 1968], and total polyphenols [Swain and Hills 1959]. Analyses of the frozen products were carried out after 3-, 6-, 9-, and 12-month storage. Since during the storage period changes in dry matter, sugar, acidity, and total polyphenols content were small and only sporadically significant, the values of these discriminants were given directly after freezing and after 12-month storage. This method ensured a clear presentation of the obtained results.

The organoleptic evaluation of the thawed product was conducted after 12-month storage. It was performed by a team of 5 standardisation inspectors, who used a 5-score scale for the quality discriminants regarded as most important from the standpoint of the consumer.

In order to simplify the interpretation of results of both the physico-chemical analyses and the

organoleptic estimate, statistical computations were conducted on the basis of the Snedecor F test and the Student t test.

RESULTS

The presented investigation concerned the effect of sucrose, low-methylate pectin, and Lascorbic acid on the selected discriminants of the chemical composition and oranoleptic traits of frozen strawberries. The substances mentioned above were used either in the powdered form or as solutions in various combinations. Their composition was based on the data from the literature, which postulated their greater effectiveness in the combined form [Garrote and Bertone 1989, Martinez-Jarega et al. 1974]. It should be stressed that the quality of the product after thawing depended on the quality of the raw material, its species and cultivar, the freezing technology, conditions and time of storage of the frozen product, and the method of thawing [Bushway et al. 1992, Hägg et al. 1995, Kmiecik et al. 1995, 1996, Wesche-Ebeling and Montgomery 1990]. In the presented investigation the above were identical for all the samples, therefore it may be supposed that the differences found in the duality of frozen strawberries resulted fromk the application of the above-mentioned components.

In the case of the traditional method of freezing strawbernes, i.e. in the loose form with no additions or with sucrose at a ratio of 1:4-5 [Kulisiewicz and Kolasa 1974, Wrolstad 1990], the obtained product is suitable for further processing and confectionery. On account of the current opinions concerning the excessive amounts of consumed sugar the present authors applied a distinctly reduced ratio, i.e. 1:10 in the case of strawberries frozen for consumption as desserts. Earlier experiments and the results obtained by different authors with respect to other species suggested that this proportion ensured good organoleptic values of the products [Kmiecik et al. 1995, 1996].

The level of the analysed physico-chemical indices in the raw material and in frozen strawberries directly after processing and after 12-month storage is given in tab. 1. The content of dry matter and sugars in frozen strawberries was related to the treatment of the raw material. Either the raw material was enriched by the addition of extract components as in the case of using of powdered sugar and sugar syrup, or it was impoverished by applying the solution of a pectin preparation. Directly after freezing, in 100 g of the product the average dry matter content reached 10,1 g in frozen fruit without the addition of any substance, 18,3 g in the product with powdered sugar, 17,3 g in sugar syrup, and 9,4 g in fruit covered with the pectin solution. In the same groups of added components the parallel sugar content was 6,6 g, 15,1 g, 14,2 g, and 6,0 g. In the period of I2-month storage of frozen products the content of dry matter manifested a certain tendency to increase owing to ice sublimation. The long storage period being taken into consideration, this increase was slight, reaching 1,5-3,2% owing to the low storage temperatures and tightness of the packages.

Contrary to dry matter, the content of sugars was lower in the product after the total storage time than that determined directly after freezing. However, the differences were fairly small, varying from 0,7-3,0%. The statistically significant differences only concerned samples 2, 4, and 7. The decreasing content of sugars during the storage period might have been induced by the respiration process and also by the formation of permanent compounds of sugars with other substances.

Directly after freezing the total content of acids ranged from 0,89 to 1,02 g in 100 g of the product, depending upon the investigated combination. The highest concentration of acids was found in the strawberry frozen without additional substances. In general, after the 12-month storage the total acidity was slightly (by 0,0-4,1%) decreased and reached 0,88-1,02 g, the statistically significant differentiation concerning only sample 9.

The active acidity (pH) of the frozen products varied between 3,35 and 3,45, always being slightly higher in the product after storage. After the 7-month storage Jarczyk et al. [1986] noted a higher total content of acids in strawberries frozen without any additional substances, irrespective of the applied freezing method, than in the raw material. On the other hand, like the present authors, Chuna et al. [1992] observed a decrease in the total content of acids during the storage of frozen strawberries.

The ratio of sugars to acids has a decisive effect on the sensory quality of frozen products. At the time of their organoleptic evaluation, i.e. after the 12-month storage, the following values of this ratio were determined: 6,3: 1 for frozen fruit without additional components, 15,3-15,8:1 for fruit with powdered sugar, 14,9:1 for fruit with sugar syrup, and 6,2-6,5:1 for fruit in a pectin solution.

The polyphenols form a group of compounds differing both in their structure and function. They are equally good substrates in the reactions of browning and as natural antioxidants [Robards et al. 1999, Wang et al. 1996]. During the 12-month storage the content of polyphenols in frozen strawberries underwent decreases, which varied between 7 and 26% depending upon the added substance. The decidedly smallest losses were found in samples with the pectin solution (7-9%) and those with the sugar syrup (10-18%). In the combinations with pectin and sucrose solutions the smaller losses can be attributed to the formation of a natural coating on the fruits, limiting the access of oxygen to their tissue. In general, smaller Iosses in the content of polyphenols were also observed in fruit frozen with an addition of L-ascorbic acid. This corroborates the opinion of Robards et al. [1999] that this acid inhibits the reaction of browning and effects the regeneration of polyphenols, though it can enhance the degradation of anthocyanins.

Vitamin C is one of the compounds Iiable to a rapid.degradation, hence the Iosses in its content were already recorded in the process of freezing and intensified during the storage period. It should be stressed, however, that directly after freezing the differences in the Ievel of vitamin C referred to 100 g of the product were statistically significant only in a few cases. They concerned the combinations without the addition of L-ascorbic acid, i.e. samples 1, 2, 3, 5, 6, and 8. Nor were significant quantitative differences recorded between samples 1, 2, 3 and 6 after the 12-month storage of frozen fruit.

Anthocyanins were distinctly more stable than the vitamin C as shown by their level determined directly after freezing and after 12-month storage. Directly after freezing their content was greater in strawberries frozen without any components added than in the remainina combinations, while the samples No. 2, 3, 4, 5, 6, 7, and 8 did not differ significantly from each other. After the 12-month storage the differences in the Ievel of anthocyanins in 100 g of the product were statistically non-significant in samples 1, 2, 3, and 4. In these samples the content of anthocyanins was greater than in the remaining combinations, especially with respect to combination 9.

The results of analyses concerning the preservability of vitamin C and anthocyanins referred to 100 a of the product tab.1 are encumbered with an error since in samples 2-9 vitamin C and anthocyanins were diluted. Hence in Fig.1 their actual content is given, the results being referred to 100 g of fruit. It should be stressed here that in the professional literature no data were found concerning the behaviour of vitamin C and anthocyanins during the storage of frozen strawberries treated with any other substances than sugar [Hong-Den and Ueda 1993, Wrolstad et al. 1990].

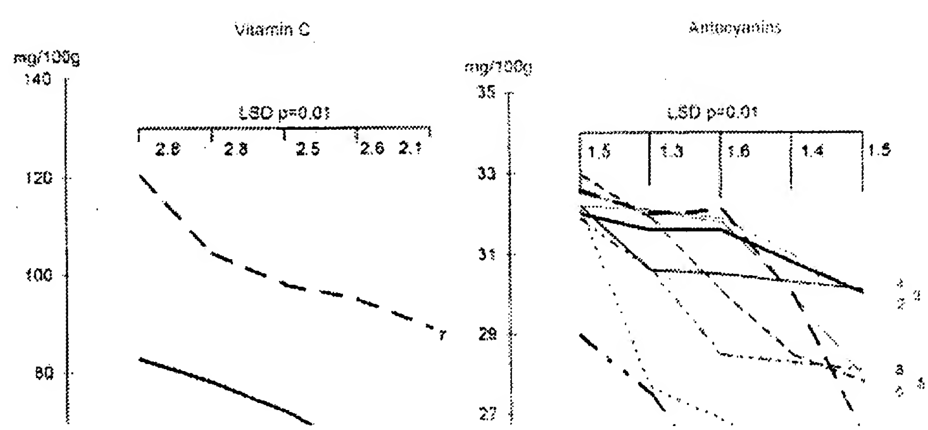
Table 1. Effect of sucrose, L-ascorbic acid and pectin on selected physico-chemical indices of frozen strawberry

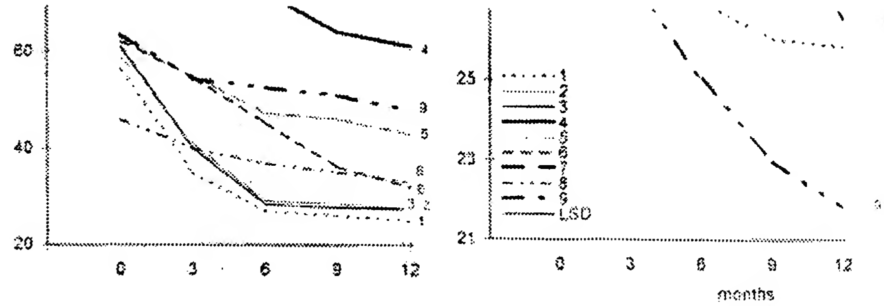
		Combinations of frozen fruit																
Item	Raw	1		2		3		4		5		6		7		8.		
	material	Period of storage in months																
		0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0
Dry matter, [g/100 g]	10,06	10,14	10,46	18,20	18,72	18,29	18,84	18,30	18,85	17,25	17,73	17,35	17,87	17,31	17,89	9,35	9,61	9,42
Total sugars, [g/100 g]	6,59	6,58	6,44	15,16	14,90	15,20	14,98	15,04	14,80	14,17	14,01	14,26	14,03	14,19	13,88	6,00	5,96	6,04
Total acids as citric acid, [g/100g]	1,00	1,02	1,02	0,95	0,96	0,97	0,95	0,99	0,97	0,90	0,88	0,89	0,88	0,94	0,93	0,94	0,92	0,98
Active acidity (pH)	3,30	3,35	3,36	3,41	3,44	3,38	3,45	3,36	3,41	3,40	3,45	3,41	3,43	3,39	3,41	1,37	3,41	3,35
Total polyphenols [mg/100 g]	155	148	111	126	94	124	92	140	112	125	107	125	102	132	119	121	113	127
Vitamin C, [mg/100 g]	62	56	25	54	25	55	25	75	55	53	37	53	27	103	76	42	30	58
Antocyanins [mg/100 g]	33	32	26	29	27	29	27	29	27	28	24	28	24	28	23	29	25	26

Combinations:

1. Frozen fruit with no additions
2. Frozen fruit in sugar
3. Frozen fruit in sugar with pectin
4. Frozen fruit in sugar with L-ascorbic acid
5. Frozen fruit in sugar syrup
6. Frozen fruit in sugar syrup with pectin
7. Frozen fruit in sugar syrup with L-ascorbic acid
8. Frozen fruit in a pectin solution
9. Frozen fruit in a pectin solution with L-ascorbic acid

Fig.1. Changes in the level of vitamin C and anthocyanins during freezing storage of strawberry, (converted per 100 g of fruit): 1. Frozen fruit with no additions, 2. Frozen fruit in sugar 3. Frozen fruit in sugar with pectin 4. Frozen fruit in sugar with L-ascorbic acid 5. Frozen fruit in sugar syrup 6. Frozen fruit in sugar syrup with pectin 7. Frozen fruit in sugar syrup with L-ascorbic acid 8. Frozen fruit in a pectin solution 9. Frozen fruit in a pectin solution with L-ascorbic acid





In the process of freezing, vitamin C preserved 57-100% of its initial content, the greatest losses being recorded in samples 4, 7, and 9, i.e. those treated with L-ascorbic acid. It is striking that in samples 5 and 6, i.e. with sugar syrup and this syrup with pectin, no losses in vitamin C content were observed. During the storage of frozen strawberries gradual decreases were recorded in the content of vitamin C. The rate of losses, however, varied in the different combinations at the different periods of analyses. In general, slightly greater losses were found up to the third or to the sixth month of storage than in the later period. After 12 months the content of vitamin C in 100 g of fruit varied from 25-89 mg. The frozen product of untreated strawberry preserved 40% of the vitamin C content determined in the raw material. In relation to the initial content, the remaining samples preserved 45% (sample No. 2), 45% (No. 3), 54% (No. 4), 70% (No. 5), 51% (No.6), 61% (No. 7), 54% (No. 8), and 43% (No. 9). The determined preservability exceeded that given for strawberries by Jarczyk et al. [1986] and Fraczek [1985] while these authors used a shorter period of storage. In general, small losses in vitamin C content during a Iong storage period can be explained by the fairly high acidity of strawberry fruit and by the low storage temperature [Albrecht J. A., Schafer H. W., Zottola E. A 1991, Hong-Den and Ueda 1993]. The differences in the preservability of vitamin C after 12-month storage between sample 1 (100% of fruit) and samples 5, 6, and 8 were higher by 72%, 28%, and 32%, respectively. They were statistically significant, this being important from the practical point of view.

During freezing anthocyanins were preserved in 87-100%. The greatest losses were noted in strawbery frozen in a pectin solution with an addition of L-ascorbic acid. They were distinctly smaller (0-3%) in the remaining samples. During the storage of frozen fruit the level of anthocyanins decreased (Fig. 1) although, contrary to vitamin C, no regularities could be observed in the behaviour of these compounds. After 12-month storage the content of anthocyanins in 100 g of fruit was 22-30 mg. Frozen untreated strawberry preserved 79% of anthocyanins determined in the raw material. In relation to the initial content the remaining samples preserved the following amounts of these compounds: No. 2 - 90%, No. 3 - 90%, No. 4 90%, No. 5 - 86%, No. 6 - 86%, No. 7 - 82%, No. 8 - 83%, and No. 9 - 67%. After the storage period all the samples with fruit powdered with sugar (No. 2, 3, and 4), fruit in sugar syrup (No. 5), in sugar syrup with pectin (No. 6), and in the pectin solution (No. 8) contained significantly more anthocyanins than the strawberry without any additions. The differences between these samples, however, did not exceed 8-15% while in the sample of fruit frozen in a pectin solution combined with L-ascorbic acid the content of anthocyanins was by 15% smaller. The opinions of different authors are not quite definite with regard to the favourable effect of sugar and L-ascorbic acid on the preservations of anthocyanins. According to Kulisiewicz and Kolasa [1974], Kmiecik et aI. [1995, 1996], and Wrolstad et al. [1990] irrespective of the form of its application sugar has a weak though always favourable effect on the level of anthocyanins in frozen fruit. On the other hand, Hong-Deng and Uega [1993] and Weinert et al. [1990] claim that the addition of the sugar syrup can increase the losses of anthocyanins. According to Zając et al. [1994] anthocyanins were Iess stable in raspberries in the presence of L-ascorbic acid. This was not confirmed by the results obtained by Kmiecik et aI. [1995, 1996] in a study on plum and raspberry, though in their investigation L-ascorbic acid was one of the components used in the frozen products.

The determination of the chemical composition of the product does not give decisively information concerning its visual attractiveness, aroma, or taste. Therefore, the organoleptic evaluation was included in the investigation, the discriminants most important from the standpoint of the consumer being taken into consideration (tab. 2). The results of analyses show the lowest sensory quality of strawberries frozen without the addition of whichever substance was used in the experiment. This product obtained the final scoring at the level of 3,71. Decidedly the highest quality was found in all the samples frozen with the addition of powdered sugar (4,58-4,65). A slightly lower scoring was found for fruit with sugar syrup: 4,32-4,65). An average quality was determined in the case of fruit frozen in the pectin solution: 3,99-4,00. In this combination statistically significant differences were found both with respect to strawberries frozen without any addition and to the remaining combinations.

Table 2. Effect of sucrose, L-ascorbic acid and pectin on organoleptic evaluation of thawed strawberry after 12-month storage

Quality factor	Conversion factor	Combinations of frozen fruit								
		1	2	3	4	5	6	7	8	9
Preservation of sahpe and exudation of sap	2	3,3	4,6	4,7	4,7	4,4	4,4	4,4	3,7	3,7
Uniformity in size	1	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,5
Colour	5	4,2	4,8	4,8	4,8	4,4	4,4	4,4	4,4	4,4
Consistency	3	3,6	4,7	4,9	4,7	4,4	4,9	4,4	3,9	3,9
Aroma	4	3,6	5,0	4,3	5,0	4,4	4,2	4,4	3,8	3,7
Taste	5	3,3	4,0	4,4	4,3	4,0	4,6	4,4	3,9	3,9
Final scoring	20	3,71	4,58	4,60	4,65	4,32	4,49	4,40	3,99	4,00
LSD p=0,05	0,202									

Combinations:

1. **Frozen fruit with no additions**
2. **Frozen fruit in sugar**
3. **Frozen fruit in sugar with pectin**
4. **Frozen fruit in sugar with L-ascorbic acid**
5. **Frozen fruit in sugar syrup**
6. **Frozen fruit in sugar syrup with pectin**
7. **Frozen fruit in sugar syrup with L-ascorbic acid**
8. **Frozen fruit in a pectin solution**
9. **Frozen fruit in a pectin solution with L-ascorbic acid**

Sugar, especially in the powdered form, favourably affected the conservation of shape, colour, consistency, and aroma of fruits. The addition of a pectin preparation to powdered sugar and to sugar syrup partly improved the consistency and taste though it deteriorated the fragrance of the frozen fruit. The addition of L-ascorbic acid to powdered sugar, sugar syrup, or a pectin solution did not significantly affect any of the discriminants analysed. In the case of strawberry, the beneficial effect of the natural substances applied consisted in the improved consistency, preservation of the shape, and inhibition of the respiration processes [Garrote and Bertone 1989, Wrolstad et al. 1990]. According to authors, the protective role is enhanced by the addition of L-ascorbic acid [Gasik 1990]. Similarly as in the case of raspberry, no positive effects of L-ascorbic acid were recorded with respect to frozen

strawberry [Kmiecik et al. 1996].

CONCLUSIONS

The substances used in the investigation considerably affected the traits of the chemical composition of frozen products. In relation to the raw material the storage of frozen strawberries for 12 months brought about a slight increase in the Ievel of dry matter, the preservation or a slight increase in the content of sugars and total acids, and also a small increase in the value of pH. Moreover. a moderate reduction in the content of total polyphenols and anthocyanins and a significant decrease in the level of vitamin C were recorded. Of the applied substances, sugar syrup and the solution of a pectin preparation had the strongest protective effect on the content of vitamin C in the fruit. Powdered sugar had a similar effect on the anthocyanins.

In general, the applied substances positively affected the sensory traits of frozen fruit. The sugar, particularly in the powdered form, beneficially affected the preservation of form, colour, consistency, and aroma of strawberries. The addition of the pectin to powdered sugar or sugar syrup partly improved the consistency and taste, reducing the smell of frozen products. The addition of L-ascorbic acid to powdered sugar or pectin solution did not significantly affect any of the estimated quality factors.

In practice, sugar in the powdered form or as a syrup may be recommended for strawberry freezing. A 1,5% solution of the pectin preparation can be used in the production of frozen strawberries for diabetics and those avoiding sugar in their diet.

REFERENCES

1. AOAC. Official methods of analysis. Association of Official Analytical Chemists. Arlington. USA. 1984.

2. Albrecht J. A., Schafer H. W., Zottola E. A. Sulfhydrvl and ascorbic acid relationships in selected vegetables and fruits. J.Food Sci. 56, 427-430, 1991.

3. Barlow S. M. Toxicological aspects of antioxidants used as food additives. In: Food antioxidants. Elser. Sci. Pub. LTD, New York, 1990.

4. Bushway A. A., Bushway R. J., True R. H., Work T. M., Bergeron D.. Handley D. T., Perkins L. B. Comparison of the physical chemical and sensory characteristics of five raspberry cultivars evaluated fresh and frozen. Fruit Var. J. 46, 4, 229-234, 1992 .

5. Chung H. D., Yun S. J., Kim B. Y., Kang K. Y. Effect of cultivars and harvest date on keeping quality of frozen stawberries. J. Korean Soc. Hort. Sci., 33, 21-30, 1992

6. Fraczek T. Ocena przydatności technologicznej nowych odmian truskawek. Przem. Ferm. i Owoc.-Warzywn. 2, 29-32, 1985.

7. Fuleki T., Francis F. J. Quantitative methods for anthocyanins determination of total anthocyanin and degradation index for cranberry juice. J. Food Sci. 33. 78-83. 1968.

8. Garrote R. L., Bertone R. A. Osmotic concentration at low temperature of frozen strawberry halves. Effect of glycerol, glucose and sucrose solutions on exudate loss during thawing. Lebensm. Wiss. Technol. 22, 264-267, 1989.

9. Gasik A. Kwas askorbinowy - właściwości i zastosowanie w technologii żywnosci. Przem. Spoż. 6. 130-133.

1990.

10. Hägg M., Ylikoski S. Kumpulainen J. Vitamin C content in fruit and berries consumed in Finland. J. Food Comp. Anal. 8, 12-20, 1995

11. Hong-Deng Ueda Y. Effects of freezing methods and storage temperature on flavour

12. stabilitv and ester contens of frozen stawberries. J. Japan. Soc. Hort. Sci. 62, 3, 633-639, 1993

13. ISO/6557/2. Fruits, vegetables and derived products-Determination of ascorbic acid content. Part 2. Routine methods, 1984.

14. Jarczyk A., Bekas W., Szumańska L., Matuszewska U. Porównanie jakości malin i truskawek mrożonych dwutlenkiem węgla i owiewowo. Chłodnictwo 21, 2, 9-12, 1986.

15. Jedrzejewska J., Wasowicz L. Eksport mrożonych owoców i warzyw ze szczególnym uwzględnieniem eksportu truskawek. Chłodnictwo 33, 9, 102-103, 1998.

16. Kmiecik W., Jaworska G., Budnik A. Wplyw różnych technik rozmrażania mrożonek z owoców jagodowych na ich jakość. Rocz. PZH 46, 2, 135-143, 1995.

17. Kmiecik W., Lisiewska Z., Jaworska G. Wpływ wybranych dodatków na jakość mrożonych śliwek odmiany Węgierka Zwykła. Rocz. PZH 46, 4, 363-37I, 1995.

18. Kmiecik W., Lisiewska Z., Jaworska G. Porównanie jakości mrożonych malin w zależności od zastosowanych dodatków. Rocz PZH 47, 4, 401-410, 1996

19. Kulisiewicz J, Kolasa J. Cukier jako czynnik podnoszący jakość mrożonych truskawek. Przem. Spoż. 28, 10, 433-434, 1974.

20. Martinez-Javega J. M., Cuquerella-Cayuerella J., Petris-Toran E. Freezing "Windsor" and "Napoleon" cherries. An. Inst. Nac. Invest. Agr. Ser. Tecnol. Agr. 1, 189-197, 1974.

21. Robards K., Prenzler P. D., Tucker G., Swatsitang P., Glover W. Phenolic compounds and their role in oxidative processes in fruits. Food Chem. 66, 401-436, 1999.

22. Swain T., Hillis W. E. The phenolic constituens of *Prunus domestica.* I. The quantitative analysis of phenolic constitunts. J. Sci. Food. Agric. 10, 63-68, 1959.

23. Wang H., Cao G., Prior R. L. Total antioxidant capacity of fruits. J. Agric. Food Chem. 44, 701-705, 1996.

24. Weinert J. A. G., Solm J., Escher F. Polymerization of anthocyanins during processing and storage of canned plums. Lebensm. Wiss. Technol. 23, 445-450, 1990.

25. Wesche-Ebeling P., Montgomery M. W. Strawbery polyphenoloxidase: Its role in anthocyanin degradation. J. Food Sci. 55, 3, 731-734, 745, 1990.

26. Wrolstad R. E., Skrede G., Lea P., Enersen G. Influence of sugar on anthocyanin pigment stability in frozen strawberries. J. Food Sci. 55, 4, 1064-1065, 1072, 1990.

27. Zając K. B., Wilska-Jeszka J., Korzuchowska A. The influence of catechins and ascorbic acid on anthocyanins stability in fruits and fruit juices. Proc. Int. Euro Food tox. 4 Conf. Bioactive substances in food of plant origin. Olsztyn, 1, 114-119

Submited:

Waldemar Kmiecik, Grazyna Jaworska, Zofia Lisiewska
Department of Raw materials and Processing of Fruit and Vegetables,
Agricultural University of Cracow
3 Podluzna Str., 30-239 Cracow, Poland
tel. (+48 12) 425 28 06
fax. (+48 12) 425 18 01
e-mail: e-mail: rrgjawor@cyf-kr.edu.pl